

DECam calibration workshop, TAMU
April 20th, 2009

DECam Daily Flatfield Calibration

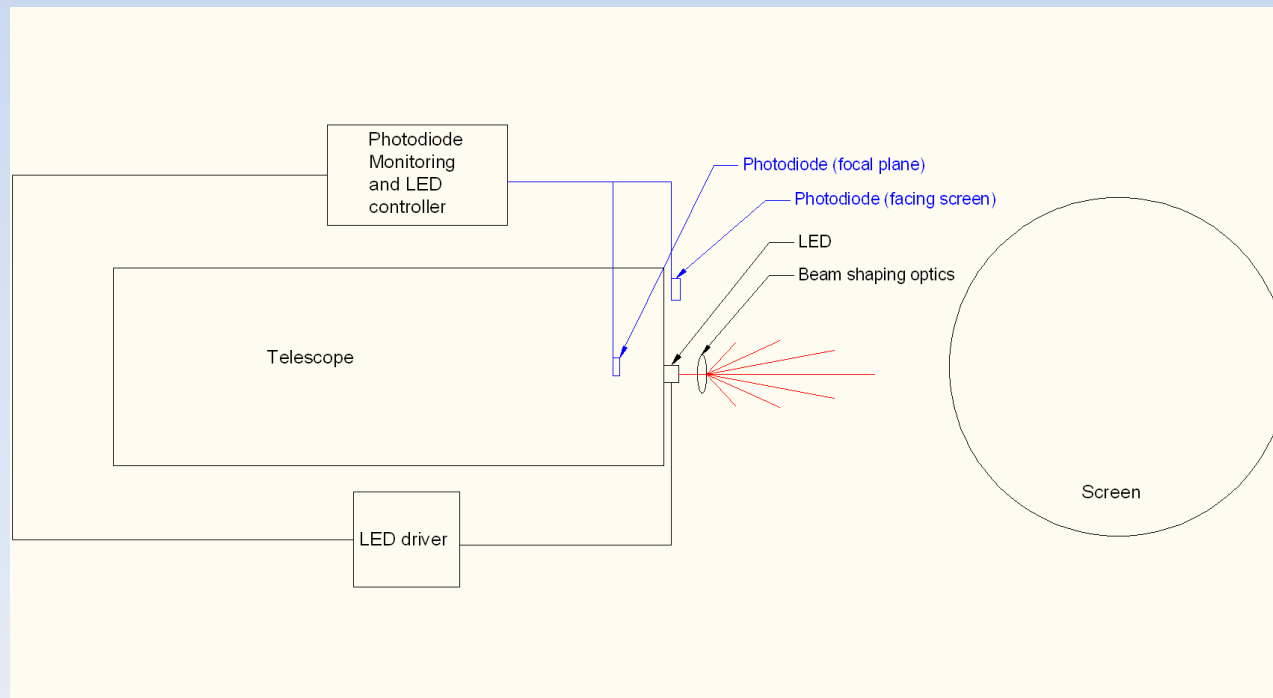
Jean-Philippe Rheault, Texas A&M University

Daily Dome Flat

- Description:
 - Traditional dome flat with improved components and more controlled operation.
 - Special attention to light source, screen properties and real-time power monitoring
- Requirements
 - Calibration in u, g, r, i, z and Y (330-1100nm)
 - Homogeneous illumination of focal plane
 - Approx 1% uniform illumination
 - Sufficiently bright to keep integration time short and allow daytime flats
 - Stable light power output (minimal drift with time or from night to night)

Schematic of the daily dome flat setup

- LED(s) placed directly on top of telescope
- Illumination uniformity insured by beam shaping optics
- Uniform, lambertian screen
- Feedback loop stabilized LED output



LEDs as a light source

- Advantages of LEDs
 - Reliable (lasts for 10,000 hours +)
 - Cheap (few \$ per LED)
 - many wavelengths available (quasi-continuous coverage from 300nm to 1500nm)
 - small footprint: can be mounted directly on top of telescope
 - Directional output (less stray light in the dome)
 - very efficient (no heat dissipation)
 - Well suited to power modulation
 - light output can be made constant over time with closed loop control (flatfield exposure time constant).

LEDs as a light source

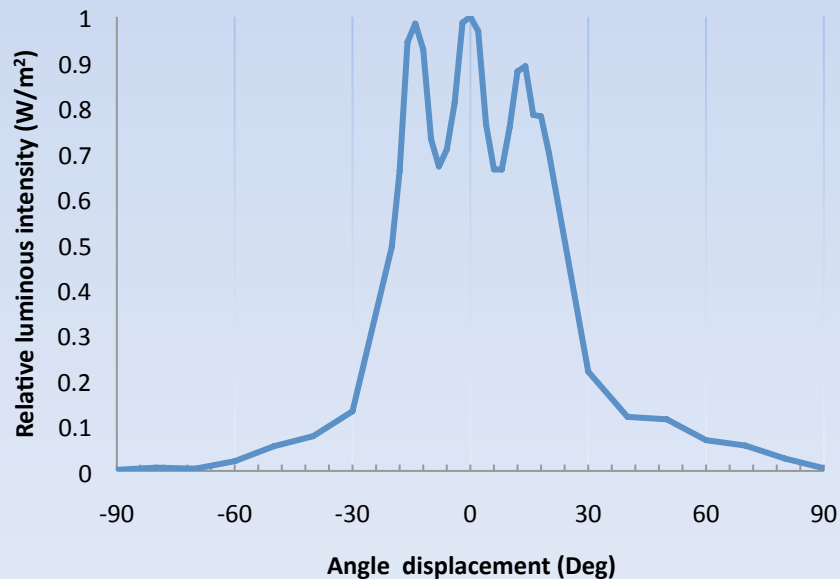
– Disadvantages of LEDs

- Non uniform Beam profile,
- (20nm to 100nm) bandwidth is narrower than a filter bandwidth.
 - We may need more than one LED per filter
 - Some “White” LEDs have wider profile but their output changes with wavelength, they have a big blue peak.

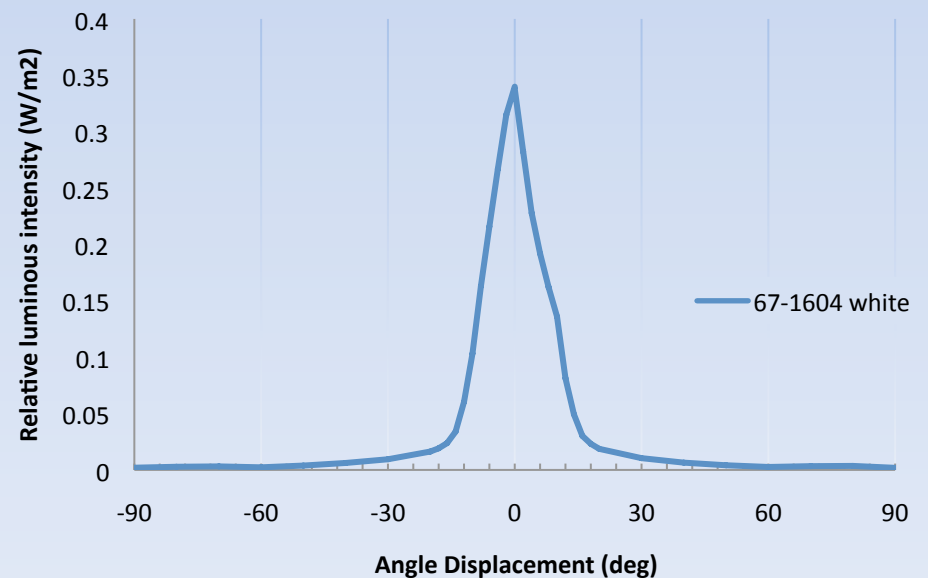
LED Characterization: Spatial Uniformity

- We built a test bench to measure the angular output of the LEDs
- LED on a rotating stage and we monitor the power read by a 1cm diameter detector at 50cm distance (1 degree resolution), while we change the angle.
- Many LED types available:
 - Narrow, wide, with a lens, diffuse

Wide LED beam profile



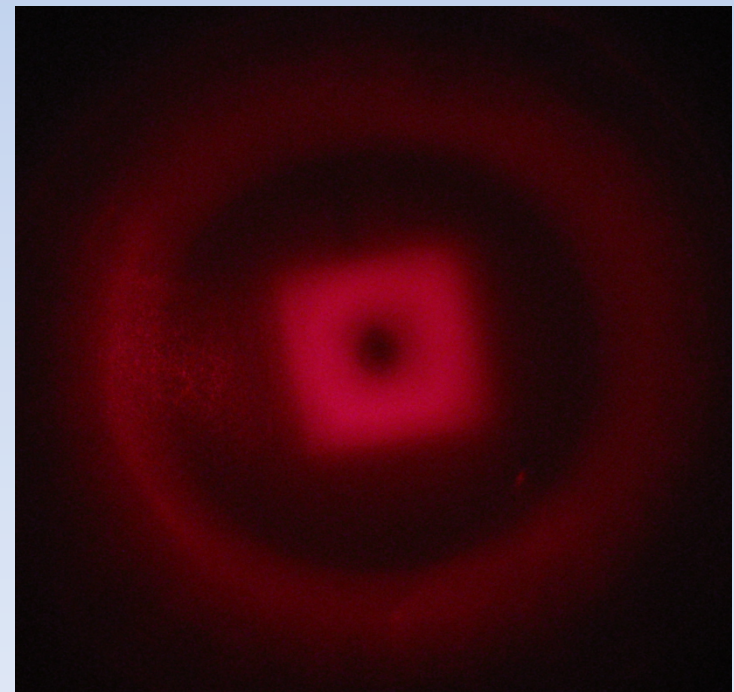
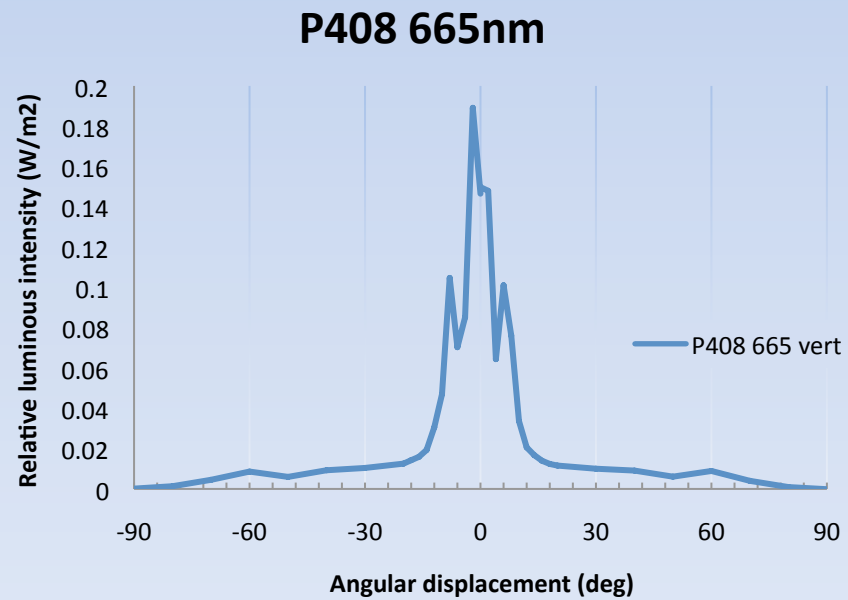
Narrow 67-1604 white



Beam shaping

- To ensure uniform illumination of the screen, each LED will have beam shaping optics
- Might even use a diffuser in front of LED.
- Uniformity can be further improved by judicious placement of the LEDs on the telescope.
 - On a ring around top
 - In the center

Example of an illumination pattern that will require optics to make pattern more uniform.



LED Characterization: Spectral output

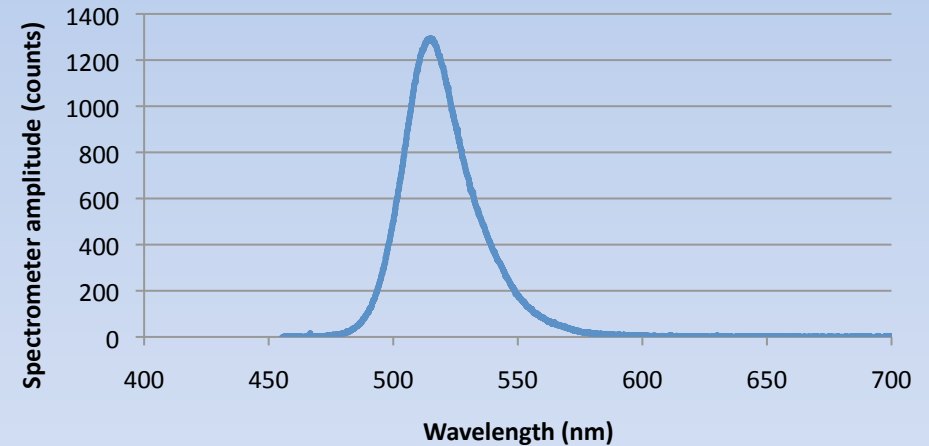
- Built a LED spectral output test bench
 - Light from LED collected in Integrating sphere
 - Fed through a fiber to a Spectrometer
 - Get spectrum from 300 to 1050 nm

Example of LED Spectra

Typical LED spectra:

- ~40 nm FWHM
- Symmetrical around max
- Smooth, no spectral features

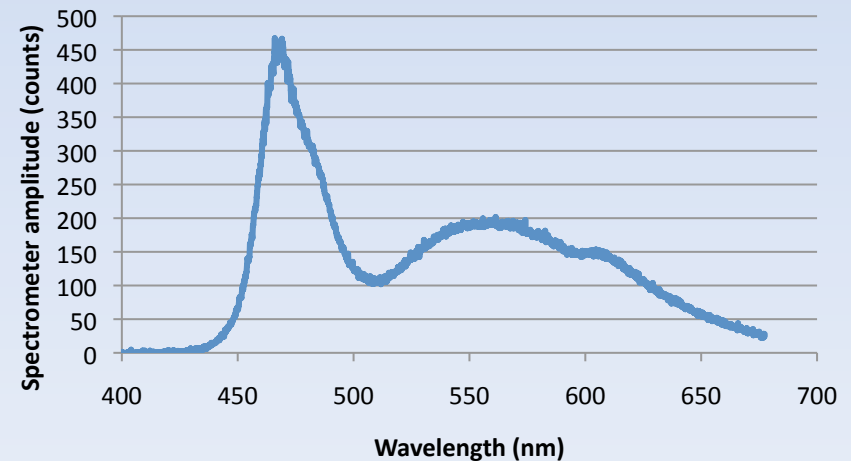
LED 160-1717



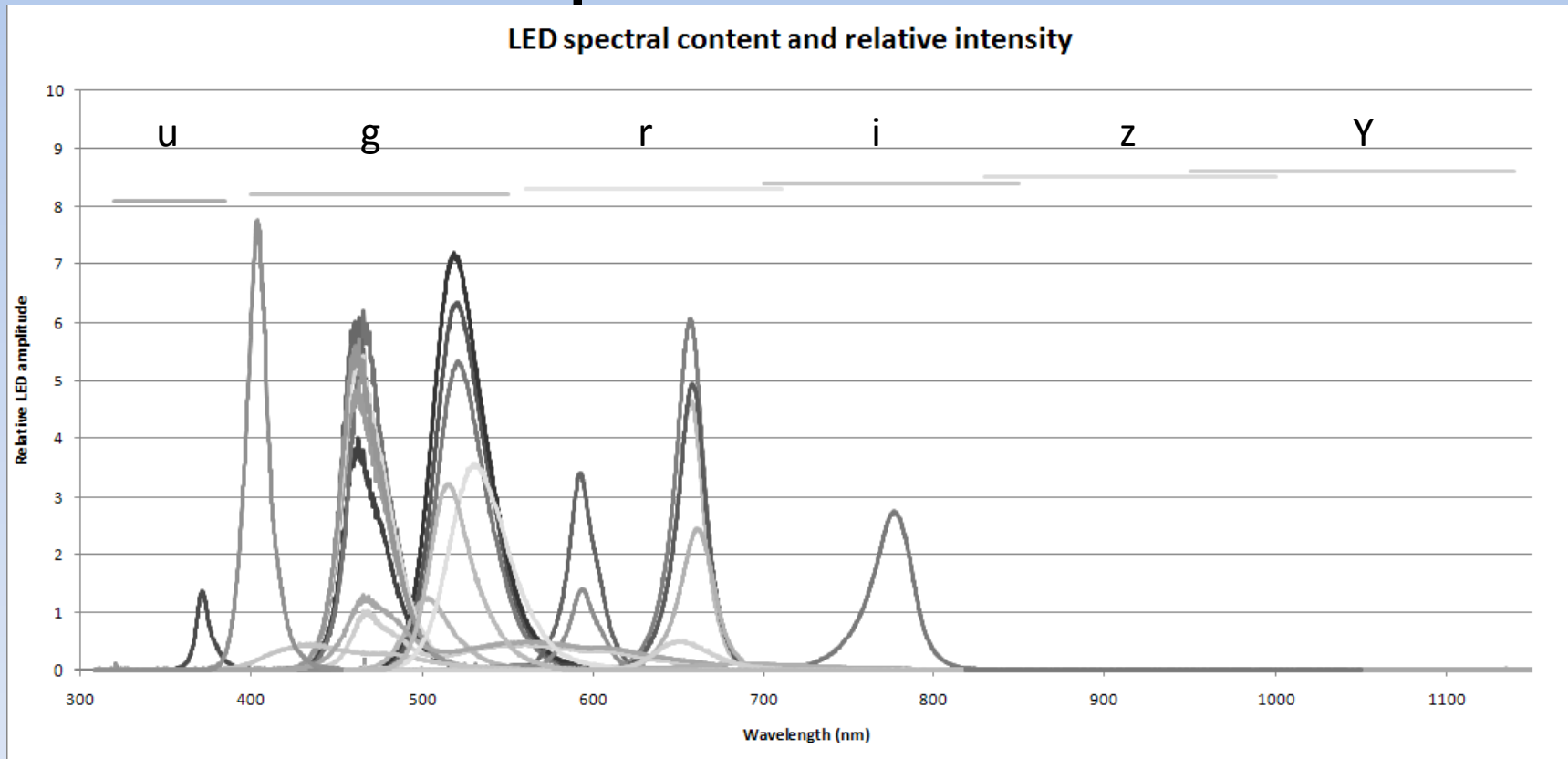
White LED spectra:

- ~ 200nm wide
- Strong spectral features
- Blue LED (480nm) with fluorescent coating

LED 67-1604



LED spectral content



Wide variety of wavelength and power

Also available for the IR , this is a limited sample from Thorlabs and Digi-key

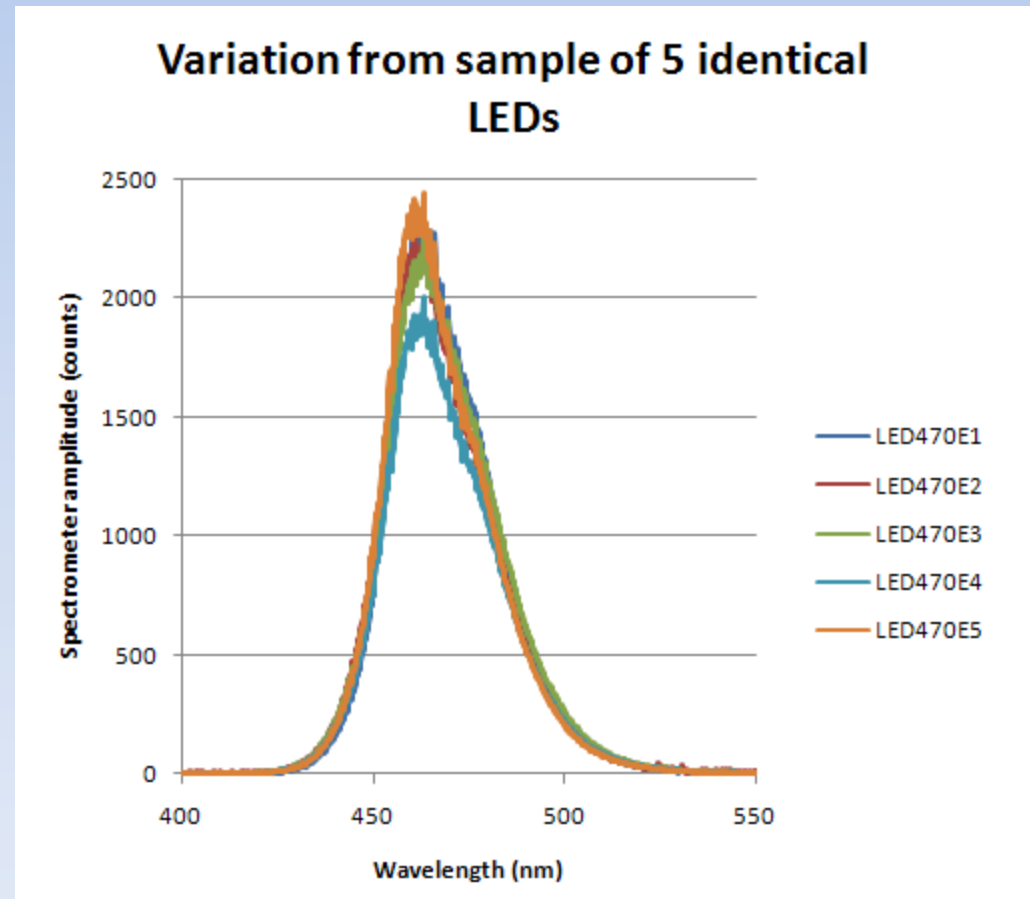
Either use a single LED in the middle of the band

Or combining 2-3 LEDs to get a more uniform profile

We can adjust the relative power of LEDs in one group by electronic modulation

Variability and long term stability

- More tests to be done
 - Spectral and spatial variations
 - Vs temperature
 - Vs drive current
 - long term drift
 - Closed loop control can correct for most of these
- We have the tools to do all that.



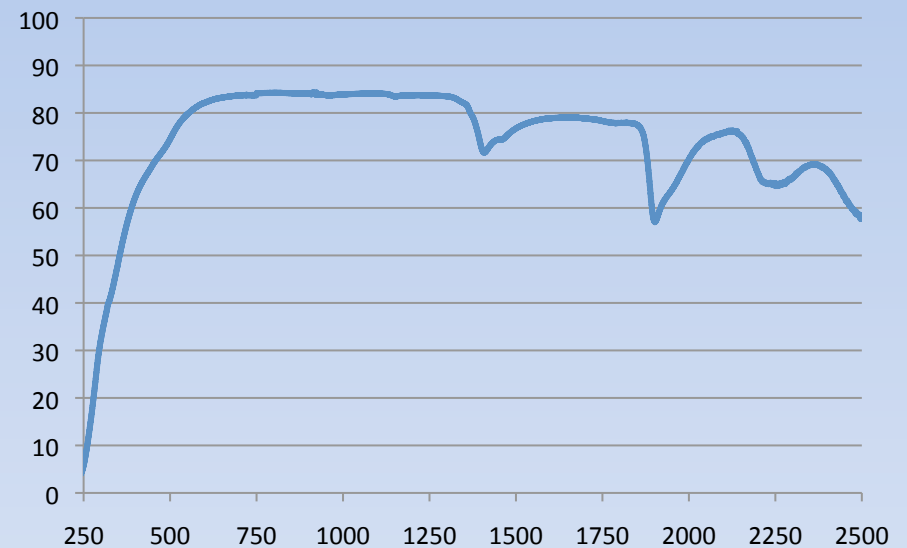
Screen

- Requirements:
 - Screen material should have good reflectivity (spectral and spatial)
 - Illumination of screen is uniform enough to get good focal plane uniformity
- Tests:
 - Total hemispherical reflectance vs wavelength
 - BRDF (Bidirectional Reflectance Distribution Function) bench. (spatial uniformity)
 - ZEMAX modeling to see dependence of focal plane uniformity

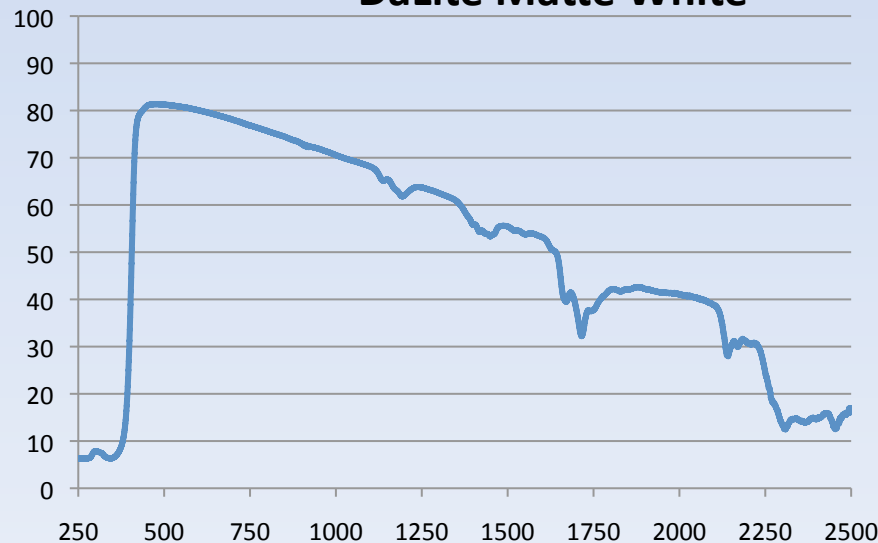
Reflectivity: Wavelength dependence

SORICSCREEN

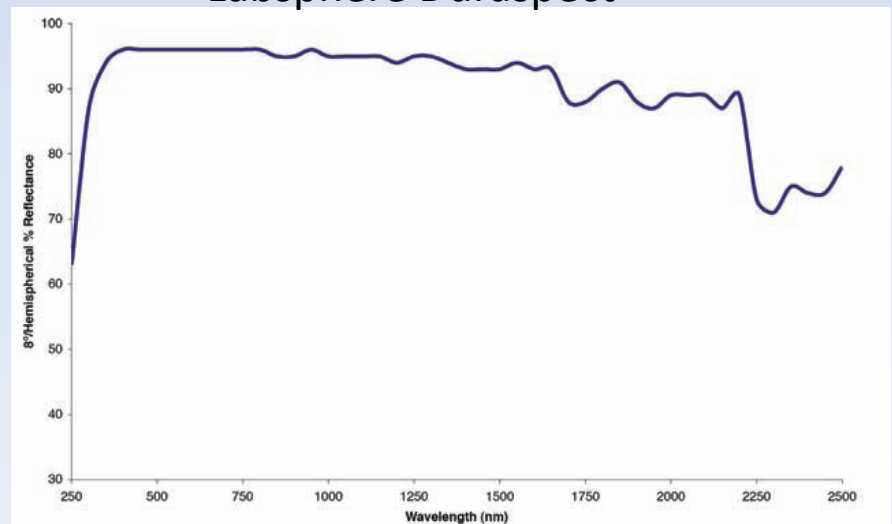
- Soricscreen, good material not available anymore
- DaLite Matte White excellent scattering properties, reflectivity dips below 400nm (TiO₂)
- Duraspect coating (paint type).
 - Extremely resistant, designed for outdoor use



DaLite Matte White



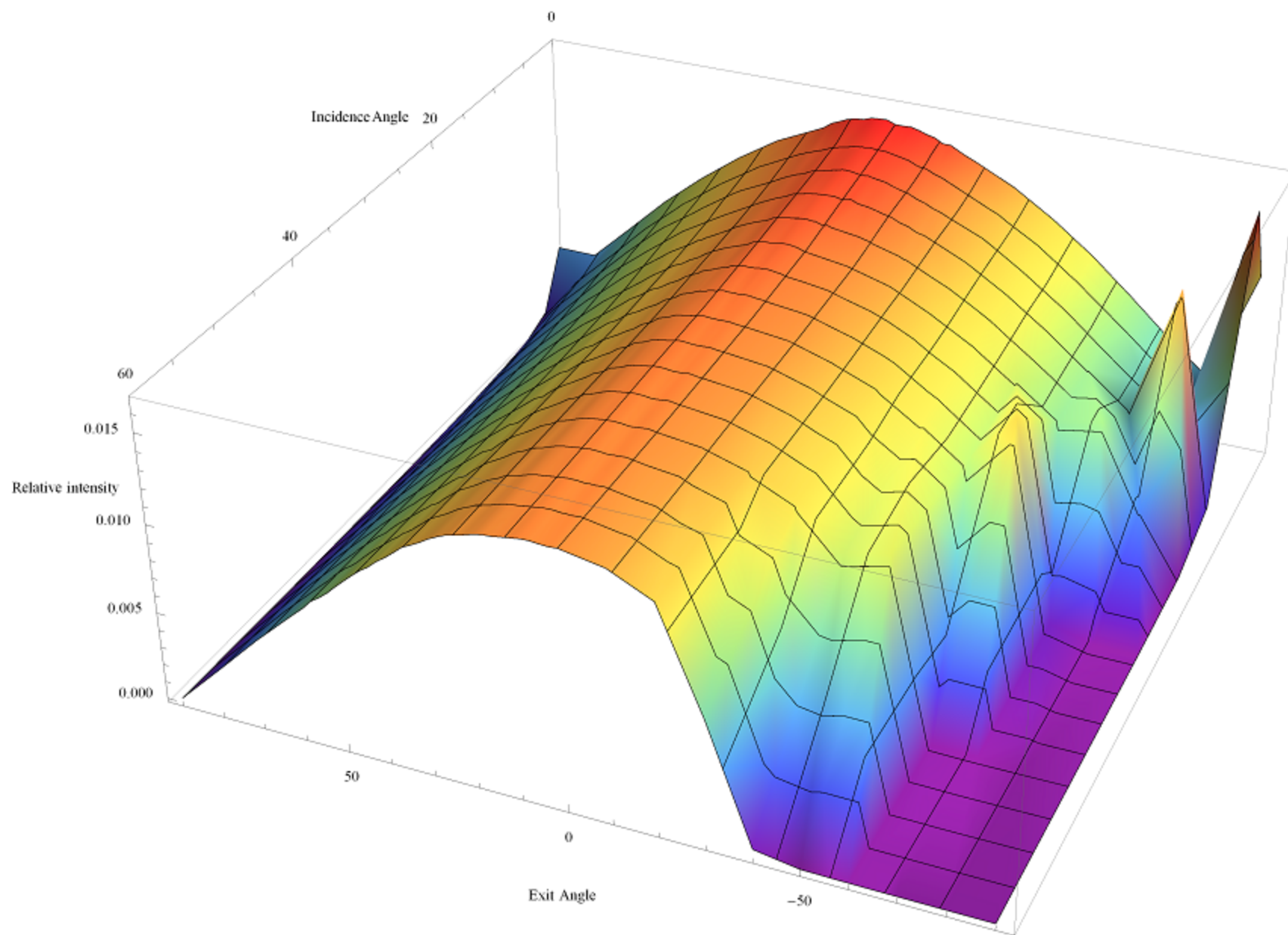
Labsphere Duraspect



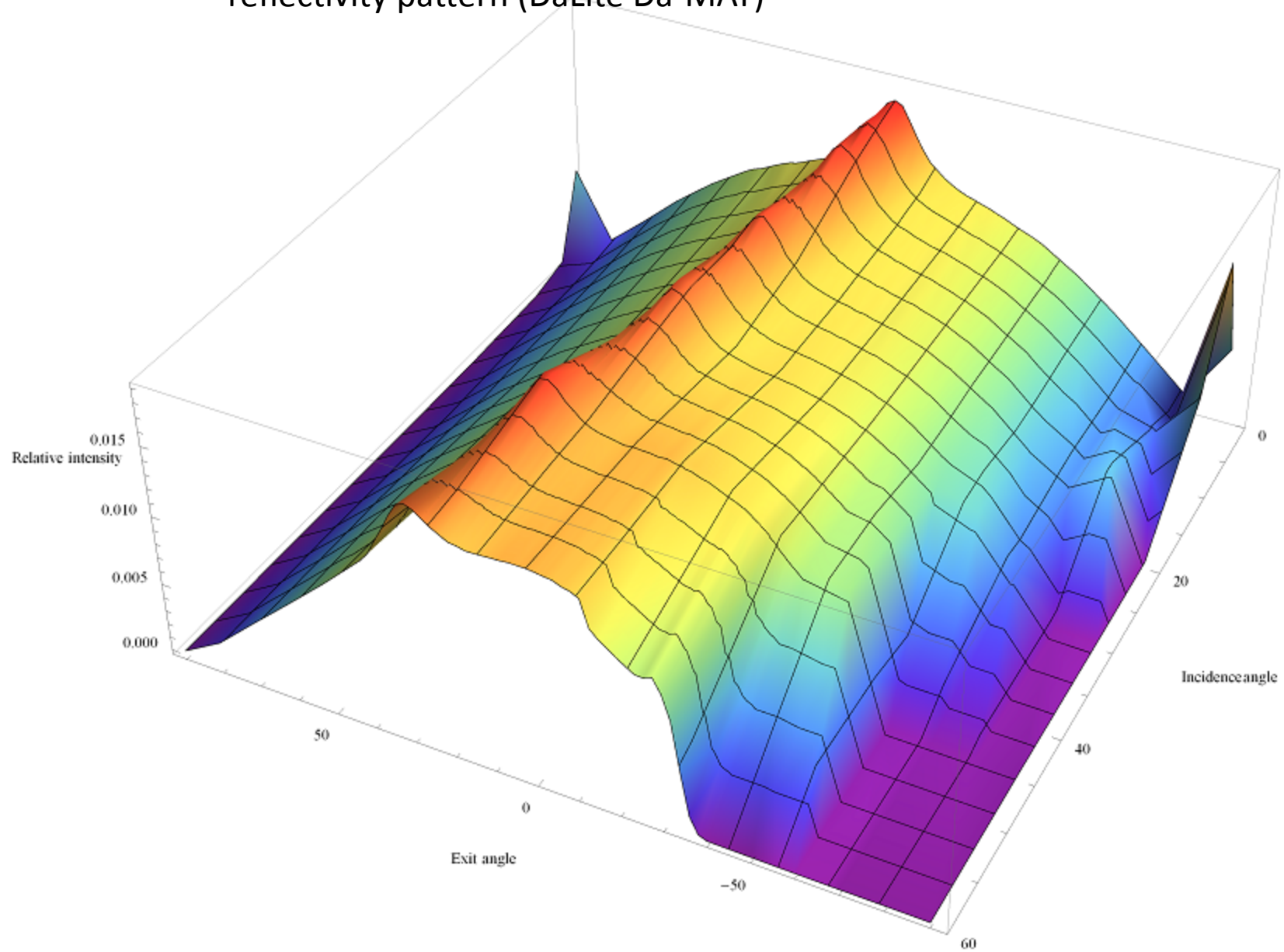
Reflectivity: spatial dependence (BRDF)

- We built a bench to measure BRDF on our screen samples
- BRDF is a function that relates the reflectivity value for any incident angle to an exit angle.

BRDF of a quasi Lambertian surface (DaLite Matte-White)

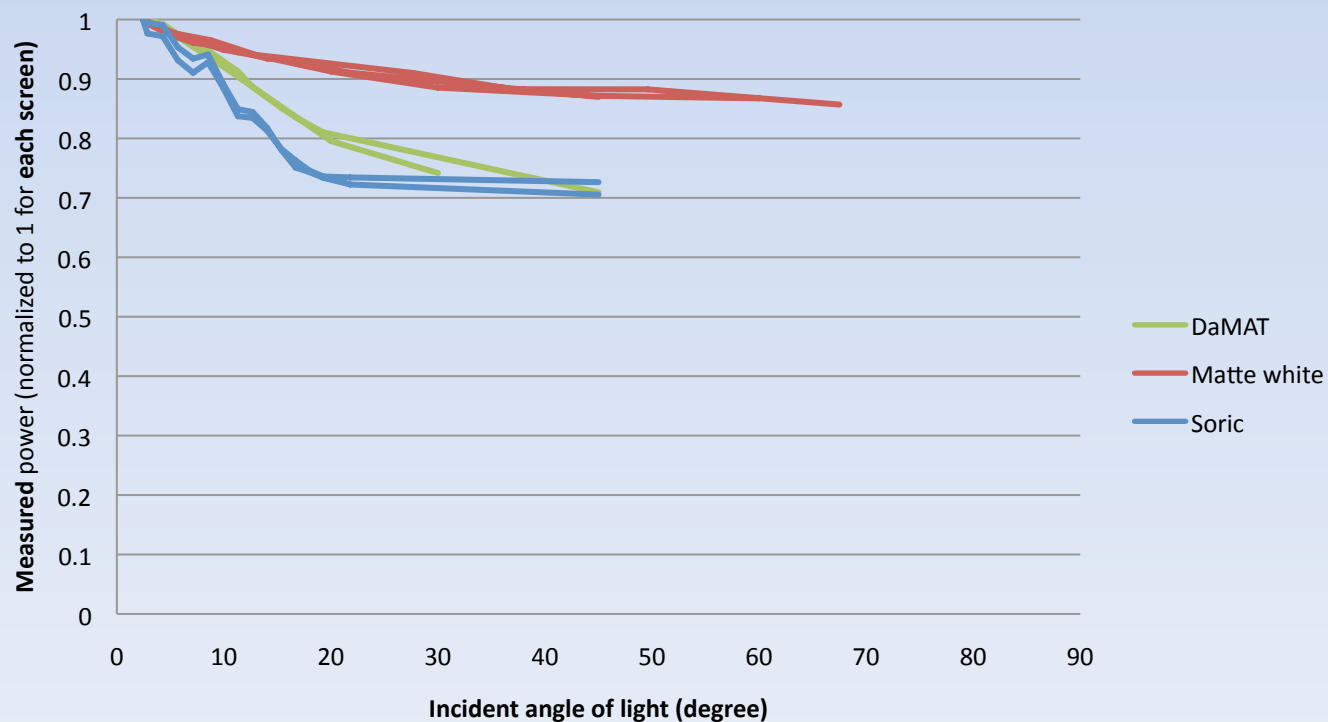


BRDF of a surface with a specular component in the reflectivity pattern (DaLite Da-MAT)



- We can simplify the BRDF
- LEDs will illuminate screen from an incident angle of 0 to 30degree
- Only light reflected within the acceptance angle of telescope ~ 2 degrees will be seen by camera
- Mirror: 1 at 0 degree, 0 everywhere else
- The reflected light would ideally remain constant for different incident light angle

Effect of incident angle on reflected light normal to the screen surface

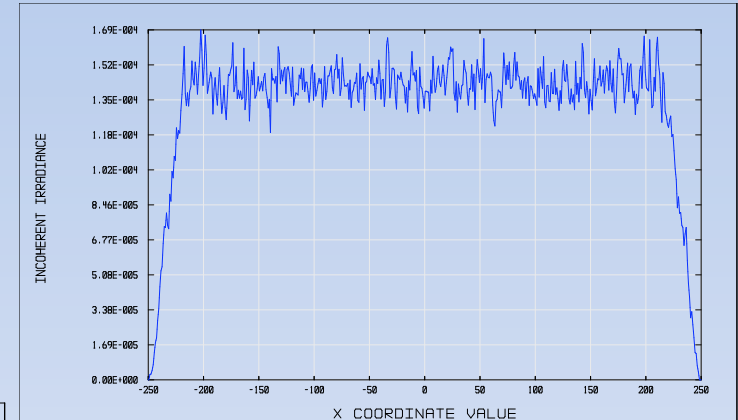
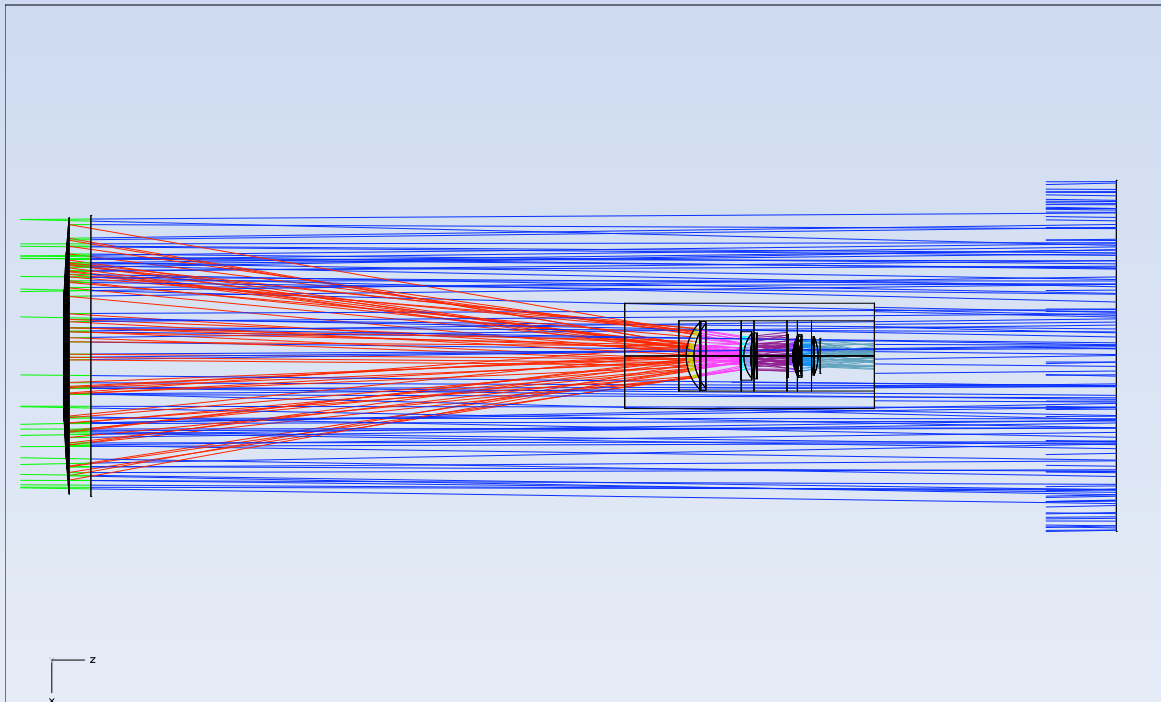


Screen selection

- Based on these results we are testing the labsphere coating.
 - Excellent reflectivity across wavelength range
 - Diffuse properties similar to Matte-White material according to manufacturer (to be verified)
- Lightweight honeycomb panels
 - got some in the lab

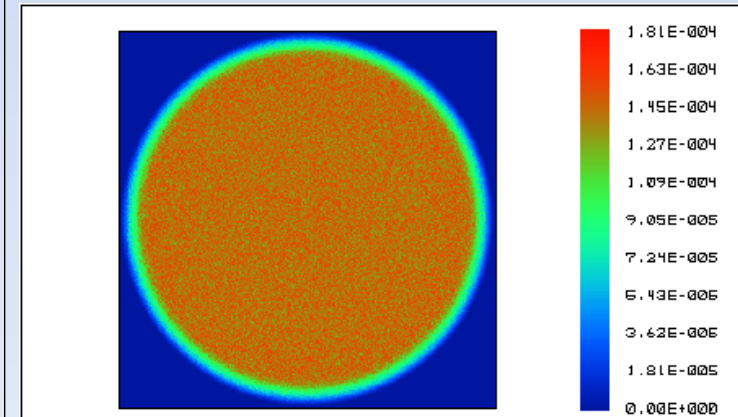
Zemax modeling

- Since the illumination pattern will not be perfect on the screen, we need to quantify how that will impact the flatfield uniformity.
- Use Zemax to model the illumination pattern from LEDs
- We can input the measured BRDF directly into the model



TUE APR 14 2009
 DETECTOR 9, NSCG SURFACE 1: FOCAL PLANE/ROW CENTER, Y = 0.0000E+000
 SIZE 500.000 W X 500.000 H MILLIMETERS, PIXELS 500 W X 500 H, TOTAL HITS = 24549864
 PEAK IRRADIANCE : 1.8094E-004 WATTS/CM^2
 TOTAL POWER : 2.4550E-001 WATTS

CORRECTED CTID NARROW 3DEGREE SCREEN SOURCE.ZMX
 CONFIGURATION 1 OF 1



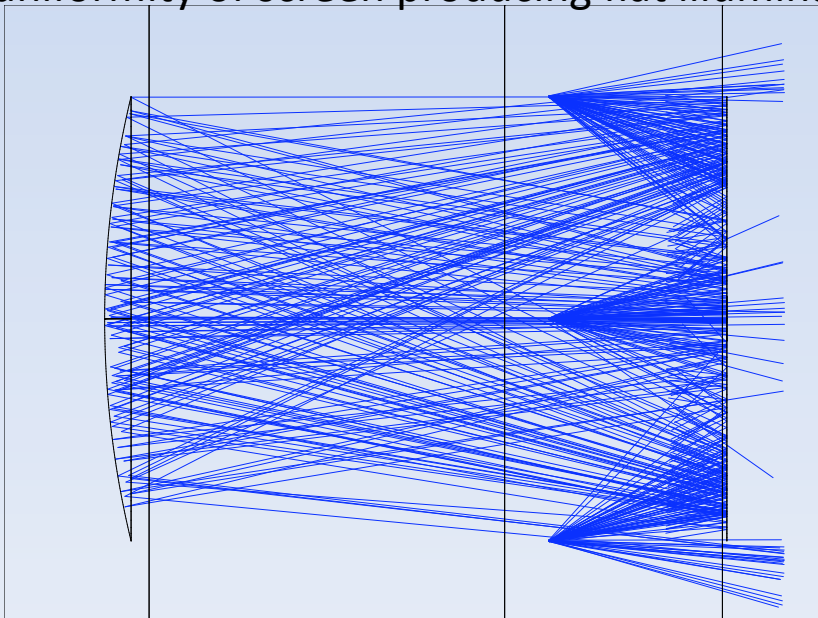
DETECTOR IMAGE: INCOHERENT IRRADIANCE

TUE APR 14 2009
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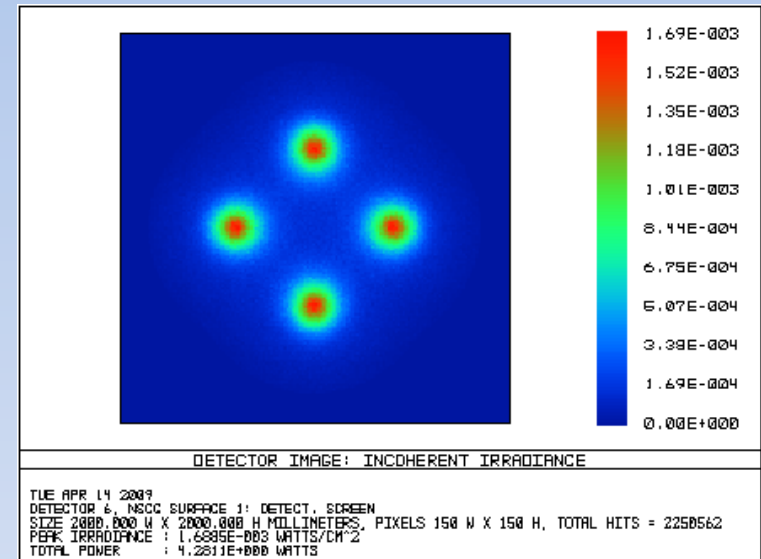
4 LED model

4 LEDs on perimeter
Very narrow LED pattern
Poor illumination uniformity on screen
Uniformity of focal plane is much better
(factor of 2)

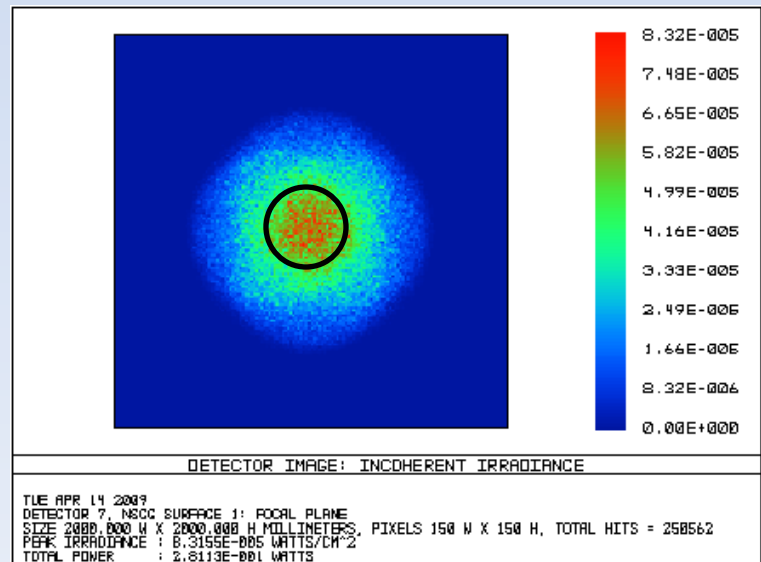
More modeling to determine the required
uniformity of screen producing flat illumination



Screen



Focal plane



Monitoring and closed loop control

- Requirement
 - Allows us to compensate for fluctuations
 - Constant exposure times
- Description
 - Photodiode facing the screen and in focal plane measure light level.
 - Closed loop system tells the LED driver to vary the electrical power accordingly to keep stable output.
 - Temperature control?

Summary

- LED will make good illumination sources
- More tests on the Duraflect screen material but looks ideal for our application
- Closed loop – photodiodes will ensure stable and repeatable measurements